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Action prediction in 10-month-old infants at high and low familial risk for Autism Spectrum Disorder

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ABSTRACT

Background: Several studies have reported action prediction difficulties in Autism Spectrum Disorder (ASD). Although action prediction develops in infancy, little is known about prediction abilities in infants at risk for ASD.

Methods: Using eye tracking, we measured action anticipations in 52 10-month-old infants at high and low familial risk for ASD. Infants were repeatedly presented with actions during which a familiar object (cup/phone) was either brought to a location usually associated with the object (cup-to-mouth/phone-to-ear; usual condition) or to an unusual location (cup-to-ear/phone-to-mouth; unusual condition). We assessed infants' anticipations to the actual target location (i.e., the location where the object was actually brought; the mouth in cup-to-mouth/phone-to-mouth actions; the ear in cup-to-ear/phone-to-ear actions) and the alternative target location (the ear in cup-to-mouth/phone-to-mouth actions; the mouth in cup-to-ear/phone-to-ear actions).

Results: Anticipation frequencies were modulated by object knowledge across all infants: We found more frequent anticipations towards the alternative target location for unusual compared to usual actions. This effect was in particular present for mouth anticipations which were also overall more frequent than ear anticipations. Across usual and unusual actions, infants showed more frequent anticipations towards the actual target location, potentially representing a learning effect elicited by the repeated action presentation. Importantly, there were no differences between the low- and high-risk infants in predictive eye movements.

Conclusion: Whereas our results suggest that familial risk for ASD does not affect action prediction in infancy, future research needs to investigate whether differences are apparent in those high-risk infants who later receive a diagnosis.

1. Introduction

Autism Spectrum Disorder is defined by deficits in social interaction and communication as well as stereotyped behavior and restricted interests (APA, 2013). Recently, various researchers have proposed that prediction difficulties may underlie multiple of the

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diverse deficits associated with ASD (Cruys et al., 2014; Gomot & Wicker, 2012; Lawson, Rees, & Friston, 2014; Pellicano & Burr, 2012; Sinha et al., 2014). Several of these accounts aim to explain the ASD symptoms from a Bayesian perspective and suggest that the inferential processes that integrate prior information and incoming sensory evidence may be affected in individuals with ASD (Brock, 2012; Cruys et al., 2014; Lawson et al., 2014; Pellicano & Burr, 2012). It is argued that atypical predictive processing could explain altered perception and sensory experiences in ASD (e.g., Pellicano & Burr, 2012), but may also result in the associated social and communication deficits by affecting the individual's ability to predict others' actions and intentions (Sinha et al., 2014). In line with these theoretical propositions, several empirical studies have reported that individuals with ASD show differences in action prediction (Boria et al., 2009; Cattaneo et al., 2007; Hudson, Burnett, & Jellema, 2012; Schuwerk, Sodian, & Paulus, 2016; Senju et al., 2010; Vivanti, Trembath, & Dissanayake, 2014; Vivanti et al., 2011; Zalla, Labruyere, & Georgieff, 2006; Zalla, Labruyère, Clément, & Georgieff, 2010). Cattaneo et al. (2007), for instance, found that typically developing 5–9-year-old children show anticipatory muscle activation when performing and observing action sequences. Children with ASD, on the other hand, lacked this anticipatory activation, both during action execution and action observation. Although these results were, at the time, interpreted in the light of a proposed deficit in the human mirror neuron system (MNS, Iacoboni & Dapretto, 2006; Oberman et al., 2005; Rizzolatti, Fabbri-destro, & Cattaneo, 2009; Rizzolatti & Fabbri-Destro, 2010; Southgate & Hamilton, 2008; Théoret et al., 2005; Williams, Whiten, Suddendorf, & Perrett, 2001), these findings are also in accordance with recent theories suggesting a general prediction deficit in ASD (Cruys et al., 2014; Gomot & Wicker, 2012; Lawson et al., 2014; Pellicano & Burr, 2012; Sinha et al., 2014). In typically developing individuals, the MNS is activated during action execution and observation (e.g., Cochin, Barthelemy, Roux, & Martineau, 1999; Hari et al., 1998), and is thought to reflect the mapping of observed actions onto own motor representations. This mapping is thought to play a crucial role in the generation of action predictions based on the observer's own motor plans (Elsner, D'Ausilio, Gredebäck, Falck-Ytter, & Fadiga, 2013; Kilner, Friston, & Frith, 2007; Prinz, 2006). A deficit in the MNS as proposed by several researchers is hypothesized to affect the mapping of observed behavior and may underlie the social deficits associated with ASD (Iacoboni & Dapretto, 2006; Oberman et al., 2005; Théoret et al., 2005; Williams et al., 2001; but see Fan, Decety, Yang, Liu, & Cheng, 2010; Southgate & Hamilton, 2008), including the reported difficulties in action prediction (Boria et al., 2009; Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009; Zalla et al., 2010).

Multiple studies assessing action prediction differences in individuals with ASD have made use of eye tracking to study anticipatory eye movements during action observation. Previous research has established that typically-developing individuals predict ongoing goal-directed actions, as they fixate the target area of an observed action before it is reached (Elsner, Falck-Ytter, & Gredebäck, 2012; Falck-Ytter, Gredebäck, & von Hofsten, 2006; Flanagan & Johansson, 2003; Hunnius & Bekkering, 2010). Falck-Ytter (2010) used eye tracking to assess whether five-year-old children with ASD showed anticipatory eye movements when observing an actor performing a series of simple actions (i.e. moving balls into a bucket). This study revealed that children with ASD showed predictive eye movements that were similar to typically developing children, suggesting intact action prediction abilities. These findings are in contrast to other eye-tracking studies that do report differences (Schuwerk, Sodian, & Paulus, 2016; Senju et al., 2010; Vivanti et al., 2014; Vivanti et al., 2011). Schuwerk, Sodian, and Paulus (2016), for instance, assessed the influence of statistical learning on predictive gaze behavior in 10-year-old children and found that the overall frequency of predictions was lower in individuals with ASD. The repetition of the stimulus lead to accurate predictions in controls but had a weaker effect on the ASD group. These findings suggest that prediction difficulties may arise when individuals are presented with more complex tasks where information needs to be integrated. Moreover, studies assessing action prediction tasks that require the interpretation of social cues or inference of mental states also report difficulties in individuals with ASD (Marsh, Pearson, Ropar & Hamilton, 2014; Senju et al., 2010; Vivanti et al., 2014). Vivanti et al. (2014), for instance, showed that predictive eye movements were influenced by the actor's gaze direction cues for control participants but not for individuals with AS. Marsh et al. (2014) investigated action prediction during the observation of rational and irrational actions, and reported that individuals with ASD looked less at the action target and had fewer trials during which they showed anticipations. However, when participants with ASD did anticipate, their goal anticipations were similar to controls in this study. Interestingly, findings by Hudson et al. (2012) suggest that while showing typical performance during action prediction, the strategy that individuals with ASD apply may differ from controls.

Taken together, these studies provide a complex picture of intact and impaired action prediction abilities in individuals with ASD (see also Vivanti et al., 2011). Findings thus far suggest that anticipatory eye movements appear typical in children with ASD in the context of a simple goal directed actions (Falck-Ytter, 2010). However, difficulties arise when individuals are confronted with more complex actions (Schuwerk et al., 2016) and with tasks that require the interpretation of social cues or inference of mental states (Marsh et al., 2014; Senju et al., 2010; Vivanti et al., 2014).

Thus far, our knowledge about action prediction in ASD is limited to school-aged children and older individuals but little is known about its early development. Yet, the ability to form and update predictions about others' actions develops already early in infancy (Falck-Ytter et al., 2006; Hunnius & Bekkering, 2014; Meyer, Bekkering, Haartsen, Stapel, & Hunnius, 2015; Stapel, Hunnius, van Elk, & Bekkering, 2010). Multiple studies have reported that infants as young as six months show anticipatory eye movements towards observed action goals (Falck-Ytter et al., 2006; Hunnius & Bekkering, 2010), similar to adults (Flanagan & Johansson, 2003). Further, toddlers' precision in predicting the timing of an observed action has been linked to the ability to act jointly with a partner (Meyer et al., 2015), stressing the importance of action prediction abilities for other social skills. Despite its early development and important role in social interactions, our knowledge about early action prediction in young children and infants with ASD to date is limited.

The early characteristics of ASD can be studied by following infants who have an older diagnosed sibling (Bölte et al., 2013; Zwaigenbaum et al., 2007) as these individuals have an increased risk of receiving a diagnosis themselves (ranging from 10 to 20%; see: Constantino, Zhang, Frazier, Abbacchi, & Law, 2010; Ozonoff et al., 2011). From past cohort studies, we know that these infants at high risk can already show behavioral abnormalities during their first two years of life (Jones, Gliga, Bedford, Charman, &